

# Geomechanical Behaviour of Shale Rocks Under High Pressure and High Temperature

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The mechanical properties of shale are demanding parameters for a number of engineering and geomechanical purposes including borehole stability modeling, geophysics, shale oil and shale gas reservoirs, and underground storage of CO<sub>2</sub> (e.g. Favero et al. 2013). Technology advances, especially in horizontal drilling and hydraulic fracturing, have enabled economic production from these formations. Shale rocks are characterized by very small grain sizes, elevated total organic carbon, and extremely low natural permeability, which usually range in the nano-Darcy scale (Vermylen, 2011; Ghassemi and Suarez-Rivera, 2012).

Characterizing these organic rich shales is an important and challenging task. Difficulties in laboratory characterization of shale rocks are related with geochemistry, anisotropy, petrophysical and geomechanical properties, and transport properties (Islam and Skalle, 2013). Furthermore, current practices involves the evaluation of the brittleness of the shale formation as a deciding factor for identifying prospect intervals for fracturing stimulation (Rickman et al., 2008). However, this practice is not based on the geomechanical behaviour of shale reservoirs, which ultimately is controlled by the conjunction of in-situ state of stresses and deformational properties. Characterizing this latter becomes a great challenge since the deformational properties cannot be captured by geophysical investigations or well logging. From geomechanical perspective, linking between the small-strain elastic properties and the large-strain deformational properties of shale gas is crucial for the exploitation of shale gas reservoirs (Sone and Zoback, 2013).

Experimental results have shown that the elastic moduli are not single-value, well-defined parameters for these rocks (e.g. Villamor Lora and Ghazanfari, 2013; Islam and Skalle, 2013). Finding suitable values for these parameters is of vital importance in many geomechanical applications. Shale rocks are known to be non-linear materials. There are many factors, including induced cracks and their orientation, partial saturation, material heterogeneity and anisotropy, plasticity, strain rate, and temperature that may have an impact on the geomechanical behaviour of these shales.

In this study, shale geomechanical properties are explored through an extensive test program. A series of hydrostatic and triaxial tests are being performed in order to evaluate the elasticity, viscoplasticity, yielding and failure response as a function of pressure and temperature. Additional characterization includes mineralogy, porosity, and permeability measurements. The shale samples were taken from a shallow Marcellus outcrop (~400 ft. deep) located in Pennsylvania. Preliminary laboratory experiments have shown that creep behaviour is significant in these shales (Figure 1a), and highly sensitive to temperature (Figure 1b). Furthermore, the non-linear nature of these rocks reveals interesting behaviour of the elastic moduli highly dependent on stress history of the rock (Figure 2).

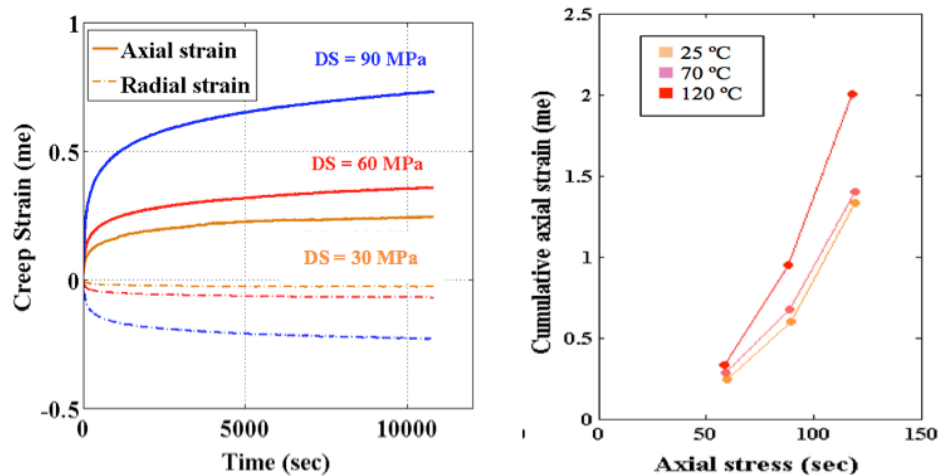


Figure 1 – (Left) Triaxial stage 3-hour creep at different Differential Stressess (Source: Villamor Lora and Ghazanfari, 2015). (Right) Triaxial stage cumulative creep for hree different temperatures.

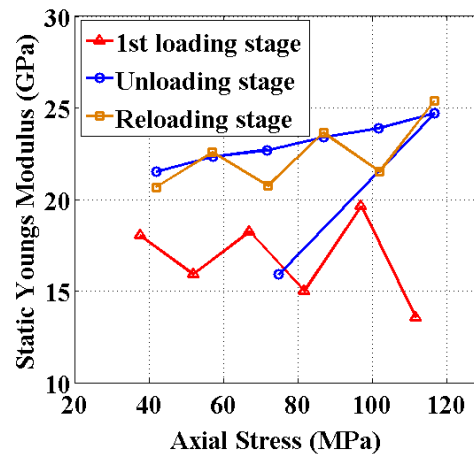


Figure 2 - Static Young's Modulus vs. Axial Stress (of a vertical sample). Source: Villamor Lora and Ghazanfari (2015)

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